California Launch Vehicle Education Initiative (CALVEIN)

An Overview & Flight Opportunities for "CanSats" and Other Payloads

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CubeSAT Workshop

JPL

April 4-5, 2002

Outline

- CALVEIN objectives and summary
- Pilot program: Prospector-1 rocket development
- Development and flight of Prospector-2
- Aerospace System Design curriculum
  - Thrust vector control system
  - Aerospike engine
  - Integration into P-2 and development of P-3
- CALVEIN lessons learned
- Flight opportunities – "*Reusable vehicles are already here*"
- Workshop: "What's next?"

CALVEIN Objectives and Summary

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- Objectives:
  - Provide engineering students of all levels with hands-on education
  - Provide upper-division engineering students with system development experience: from requirements definition to hardware dev. and flight
  - Stimulate interactions between small payload dev. & launch communities
- Spring 2001: "*From an empty lab to the flight of Prospector-1*"
- CSA/CTTCA funding received in June 2001 to expand the program
- "System integration lab.": => P-2
  - Get hands-on experience by integrating rocket components
  - Develop/improve reusable rocket subsystems
- Aerospace System Design Curriculum: => P-3
  - From requirement definition to flight tests
  - Develop aerospike engine & thrust vectoring system
- Workshop in June 2002
  - Focused on low cost RLV development
  - Small payloads

Pilot Program: Spring 2001

- Initiated collaboration with Garvey Spacecraft Corp. (GSC)
- Established ***goal of launching before the summer***
- Objectives: provide hands-on experience to engineering students
- GSC provided a “kit rocket” based on their Kimbo V vehicle as well as support for assembly and operations – Prospector-1 (P-1)
- P-1: 160 lb, 10 in dia., 12 ft long, LOX/ethanol, ablative engine, 7,500 ft altitude
- Students (ME & AE) developed a 1000 lbf thrust engine (Kimbo-V had a 500 lbf engine)

Pilot Program: Spring 2001

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Prospector-1: Spring 2001

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May 20, Static fire of student engine…

June 3, Flight & recovery of Prospector 1 (P-1)

System Integration Lab. – P-2

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- P-2: “Basic” vehicle with medium-level modifications
- Students of all levels integrating the components provided by GSC

- New subsystem development/improvements:
  - Initiated digital telemetry system dev. (EE)
  - Improved 1000 lbf engine design and manuf. (AE & ME)
  - Filament-wound composite aeroshell from ACPT
  - New student-developed recovery system
- Stanford provided payload and recovery electronics

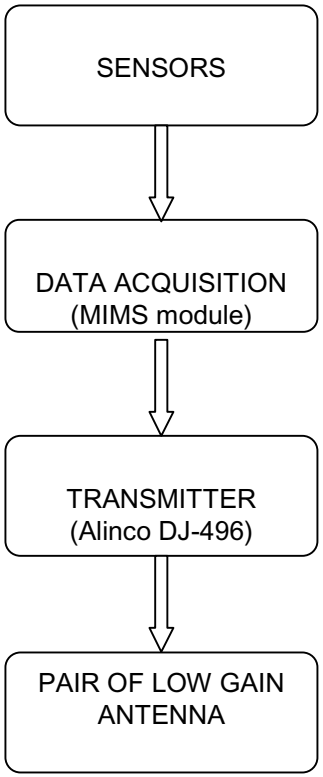
Telemetry System Development

- Telemetry Project builds upon previous experiments
- Implement real-time digital telemetry, GPS tracking
- Utilize amateur radio equipment, protocols
- Stanford providing technical guidance: based on small satellite technology
- Could become standard for other rocket projects

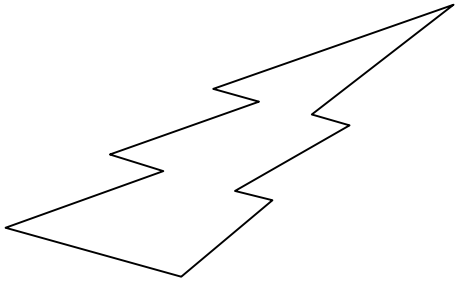
EE students fabricating electronics box for Prospector 2

Telemetry System Development

Flight Vehicle

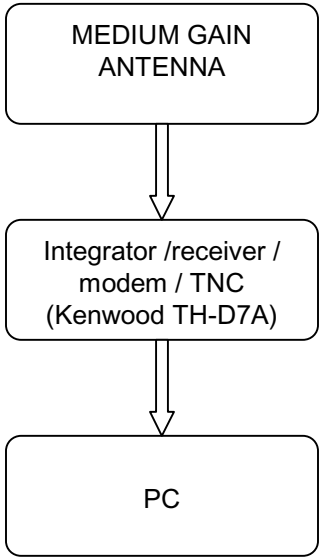


- tank pressures
- atmospheric pressure
- acceleration
- magnetic field
- temperature
- binary events



UHF
1200 bps
AFSK
AX.25

Ground Station



Dec. 1, 2001: P-2 Static-fire Test

- Static fire test of new 1000 lbf engine
- Use of static test stand developed by GSC and integrated into the RRS VTS-2
- Validation of P-2 airframe
- Flight of telemetry system proof-of-concept onboard Kimbo-IX

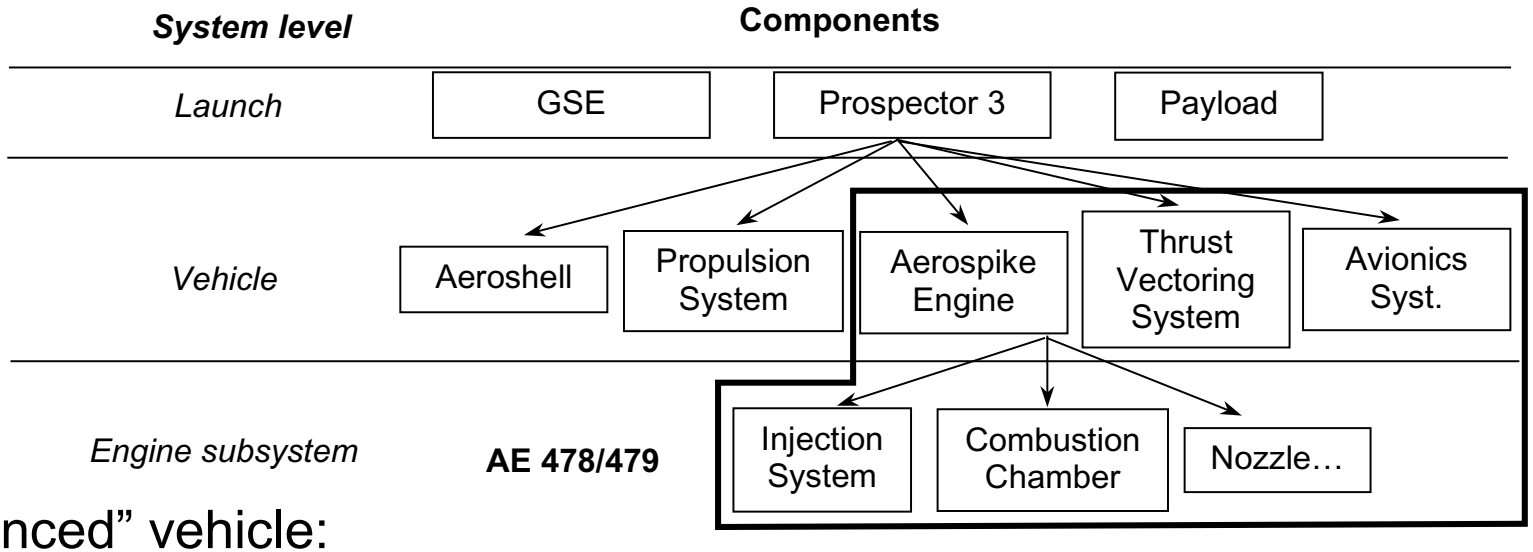
K-IX with "proof-of-concept" telemetry system

P-2 Launch and Recovery

- Flight of telemetry system
- Payload deployment system: Stanford students
- Stanford flight computer: 6000 ft peak altitude

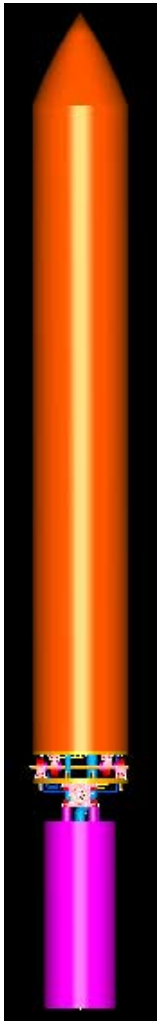
System Design Curriculum

- Aerospace System Design Curriculum (2 semester design course)
  - Systems Requirement & Functional Review; Oct. 01
  - Preliminary Design Review; Dec. 01
  - Critical Design Review; Feb. 02
  - Test Readiness Review; April 02
  - System Verification Review; May 02

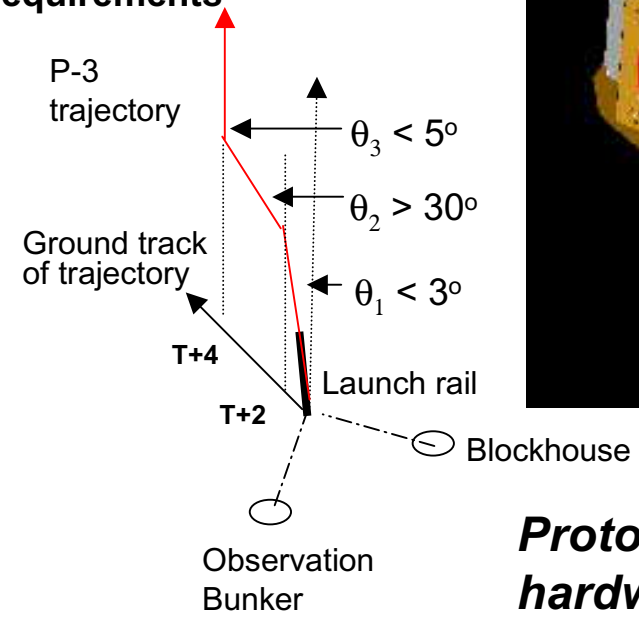


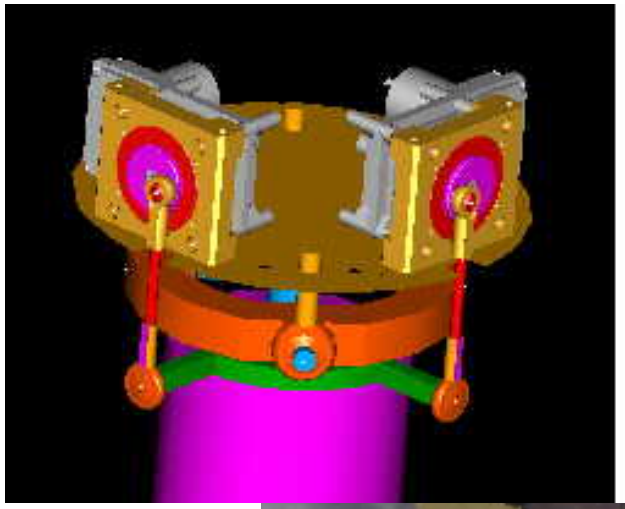
- "Advanced" vehicle:
  - Thrust vector control
  - Aerospike engine

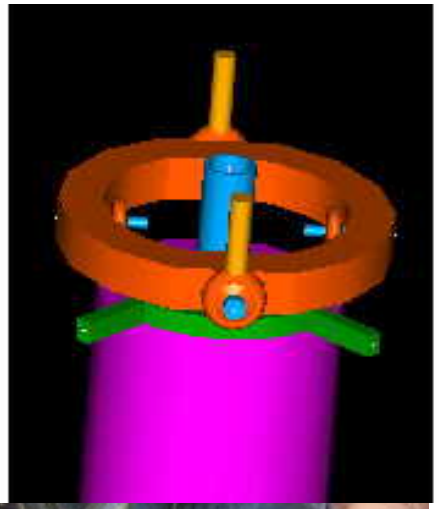
TVC: 2-Axis Gimbal System



Functional requirements





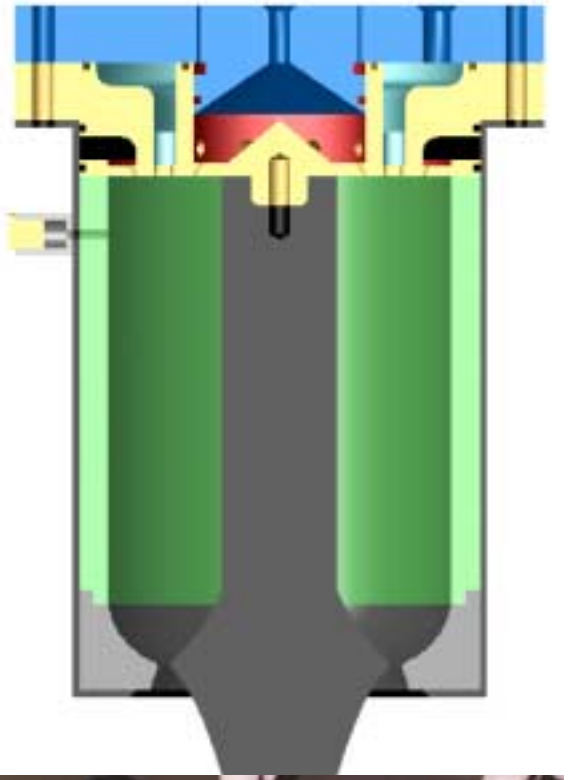


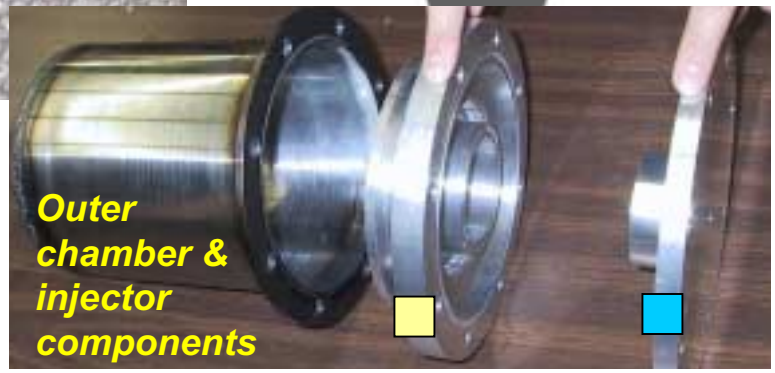
Prototype hardware

- Static fire: May 2002
- Flight test (P-3) : June 2002

Aerospike Engine

- Requirements
  - 1000 lbf thrust
  - Min. of 6 sec. Burn
- Static fire: April 20, 02
- Flight test: early May 02
- Reuse P-2 vehicle





Successful flight (of first aerospike engine) will represent a technical milestone in the history of rocket propulsion development

CALVEIN Lessons Learned

- Set achievable goals: technically & in terms of schedule and cost.
  6 months – 1 yr. time frame
- Need to establish a schedule with measurable milestones and need to STICK to the schedule
- Students need NOT design/build/test everything
- Providing a “hardware kit” can help drastically jump-start a program
- Focus on incremental improvements
- Student projects need experienced mentors on both technical and management aspects
- New subsystem development should be non-critical path, e.g. engine (P-1 had a 500 lbf backup engine)
- Students put more attention and effort into a piece of hardware which they truly believe is going to fly

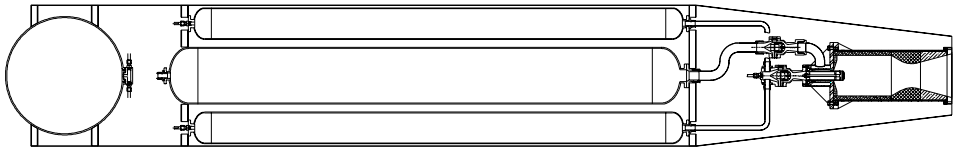
Flight Opportunities – Near term

- 10 in diameter x 1 ft length payload bay
- Up to 5 lbs
- Up to 5 g's acceleration

- Altitudes less than 10,000 ft
- No payload deployment
- P-2 with aerospike engine: May 4, 2002 (targeted date)
- P-3 with TVC system : June 2002

Flight Opportunities – Longer term

- Similar vehicles & flight profiles, possible payload deployment
- Improved vehicles: higher altitudes, larger payloads, etc.:
  - 12,000 lbf. vehicle now in development @ GSC
  - Students already participating



CALVEIN Workshop: “What’s next?”

- Objectives and scope
  - Coordinate efforts in academia and interests of small aerospace companies regarding:
    - launch vehicles
    - payloads
  - Explore opportunities for adapting small satellite technologies to launch vehicles
  - Address the needs of the small satellite community:
    - “Low” altitude flights
    - Sub-orbital flights
    - The future: achieving low cost orbital flights
- CSULB, mid-June (2002)
- Format:
  - Session 1 (morning): Review of existing programs
  - Session 2 (afternoon): Workgroup: “What’s next?”